

ART. XIII.—*On the Sections of the Delta of the Yarra,
displayed in the Fisherman's Bend Cutting.*

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THE raised beaches around the shores of Port Phillip—at Portarlington, Frankston, Cheltenham, Brighton, &c., everywhere marked where the cliffs are high enough to prevent any confusion of the old with the present shores—have a great interest in their bearing on the question of the changes in physical features which have taken place in the Port Phillip district in post-tertiary times. The task of collecting evidence of any value is, however, tedious, and as the shells of these deposits are in the eyes of zoologists not quite recent, and in those of geologists scarcely fossil, they have not attracted the serious attention of working naturalists. Usually met with in natural cliff-sections, or laid bare on the present shores, all more or less weathered, fractured, and fragile, these shells and their record have not yet been diligently read. Yet a careful study will repay those who would accurately determine the changes which have taken place about our coasts during the recent period.

A special opportunity has occurred of examining these post-tertiary deposits at a distance from the sea, and in extended and freshly-exposed vertical sections, in the ship canal, or straight cut, recently completed to enable the shipping to avoid the dangers and delays of the Fisherman's Bend. My attention was directed to the matter by Mr. D. Davies, of the Melbourne Harbour Trust; and after paying a visit to the canal I fully agreed with him as to the importance of preserving a record of the sections, certainly the most extensive hitherto obtained, or likely to be obtained in the future, of the beds which form the delta of the Yarra. Accordingly I have paid several visits to the ground, noted the stratigraphy carefully, and collected as many relics of life and traces of mineralisation as possible in the somewhat limited time that has intervened between my first visit and the admission of the water. I have to tender my thanks

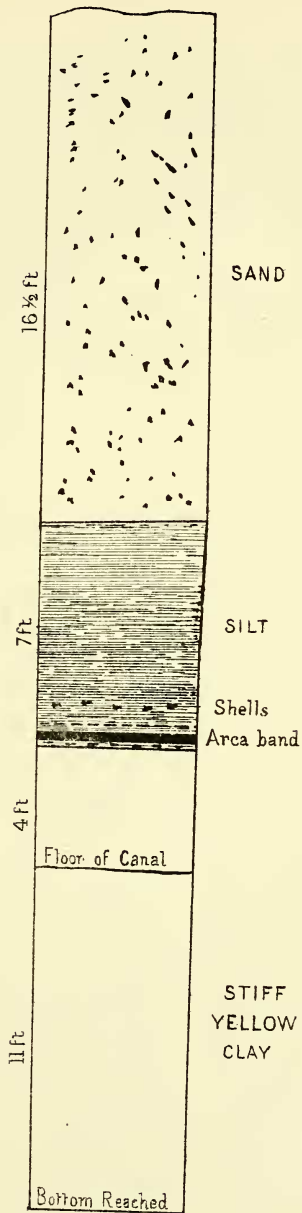
to the Commissioners and the chief engineer of the Melbourne Harbour Trust for permission to make use of the data of precision, the plans and borings, prepared for the construction of the canal; and I must also make my acknowledgments to Mr. Davies and Mr. Meldrum, of the Trust, who have given me very ready and intelligent assistance in the inquiry on the spot.

The canal is 6000 feet in length. It forms a curve, with 6000 feet as its shortest radius, trending nearly east and west, and roughly conformable to the north shore of Hobson's Bay. The average distance from the Bay is 7200 feet across the Sandridge flats; the west end of the canal is 4600 feet below the confluence of the Saltwater and Yarra, and 12,600 feet from the sea extremity of the stone walls, both measurements being taken along the present water-courses. The width of the canal at low-water is 260 feet, and the depth of the exposed excavation prior to the dredgings 20 feet below low-water mark. I may say that there is no appreciable difference between the level of low-water in the Bay and at Falls Bridge. The surface of the ground being about $7\frac{1}{2}$ feet above low-water, the total vertical depth of the sections exposed was 27 feet; at one point the depth reached 31 feet.

Throughout the canal the appearance and sequence of the beds excavated are as follows:—The floor and the lowest part of the walls to a height of 4 feet on the average consist of a stiff yellowish clay, in which no traces of life have been detected. The greater part of the side walls is formed of a compacted, fine-grained black silt, having an average thickness of 7 feet. Above the silt is a capping of sand, with an average thickness of $16\frac{1}{2}$ feet, and reaching to the surface. Both silt and sand contain marine shells. The sections are fairly uniform from end to end of the canal, though the silt drops from 8 feet to 5 feet from W. to E. Only in one notable depression, to be dwelt on at a later stage, does the silt dip below the floor of the cutting, and in no case does it come within 13 feet of the surface of the ground.

The upper surface of the very stiff yellowish clay, as shown in the face of the sides, is roughly horizontal with irregular undulations, whose amplitude never exceeds 3 feet. There is but one marked inequality in the general level, the exceptional depression referred to. The hollow is filled with silt, continuous in bedding with the main mass. The

COODE CANAL
Vertical Section



average depth below low-water mark of this upper limit of the clay is 16 feet. The bed of the canal is 4 feet lower, and the clay was still found to be present in a channel cut 11 feet deep in the floor for the passage beneath the canal of the Yan Yean main water-pipe. How much deeper the clay extends is not known, but it has thus been traced for 15 feet. No animal or vegetable remains have been found in this clay, but Mr. Davies informs me that he has obtained nodular concretions at one point.

There is, as we have said, one remarkable exception to the general uniformity of level in the surface of this unfossiliferous clay. This occurs in the form of a linear depression stretching across the canal near the east end. As seen in the floor of the canal, the sharply-defined borders are two parallel lines running across the floor, with a trend N. 30 degs. W., S. 30 degs. E., and making an angle of 45 degs. with the banks of the cutting. The perpendicular distance between the borders is 200 feet, and the distance of the centre of the parallel band from the east extremity of the canal 550 feet. As seen in the sides the sections of the depression are gently sloping curves of slight concavity. This hollow is filled with the black silt, and the shell-layers dip into it with a corresponding curvature. It is evidently, I think, an old channel of the Yarra, or of one of its estuarine branches.

Above the clay lies a thickness of about 7 feet on the average, increasing to 10 or 12 feet towards the east end, of blue-black silt, of estuarine origin. The lowest stratum of this silt, resting on the clay conformably to the curvature of its very moderately undulating surface, is a remarkable layer of about 15 inches average depth, crowded with marine shells, all of species still to be found in the Bay. Near the surface of junction a thin layer forms a conspicuous white band, which, as one stood on the summit of one bank of the canal, could be traced readily by the eye, extending throughout the visible portion of the opposite slope. The usual thickness of this band was 3 inches, but in some places it divided into two, or even three, branches; but these were exceptional, and never occupied a greater thickness than a few inches. It was composed of thousands of specimens of *Arca trapezium* (Desh), with a large number of oysters, *O. edulis*. Both species assuredly lived on the spot, as evidenced by the greater number occurring with the two valves united, and by the presence of multitudes of indi-

viduals of all ages and sizes. The enormous number of shells crowded into this layer, and the vast areal space occupied by it, will be realised by anyone who sees large portions of the new-made ground on the Port Melbourne side of the river covered with the valves of the arcas and oysters. The bed had been previously reached in the river dredgings, but its exact position and dimensions had not been determined.

It was suggested to me that the arcas and oysters were all killed by an incursion of fresh water, as the upper limit of the arca bed is apparently definite, and the dense deposit of silt commences above. But as the casts of the shells are of the same silt as occurs in mass above—as marine shells occur, more or less, throughout the silt, while scattered arcas are to be found, though rarely, amongst the shells of the lower layer of the silt—it is clear that there is no evidence of fresh-water influx. The deposit of shells ceased, probably because the depth of salt-water became no longer sufficient, and the arcas and oysters migrated outwards to deeper waters. The bivalve shells, too, all contain a core of silt, which has contracted on drying, so that the silt cast is smaller than the cavity of the shell. This would not have been the case had the shells been filled with mud from above. The oysters are fine specimens of the mud-oyster, often 6 inches across.

In addition to these, the two most prevalent forms, I also obtained the following from the lowest 18 inches of the silt:—*Cardium tenuicostatum*, Lam.; *Mytilus latus*, Lam.; *Natica conica*, Lam.; *Cominella ulveolata*, Kilner; *Ampullarina fragilis*, Quoy.; *Cylichna arachnoides*, Quoy.; *Philine Angasi*, Sow.; *Venus lævigata*, Lam.; *Tellina deltoidalis*, Lam.; *Nassa fasciata*, Lam.; *N. pauperata*, Lam.; Balani, Polyzoa, Driftwood.

Several fragments of driftwood were found on the arca horizon. One piece was covered with balani. I am indebted to Mr. Meldrum for pointing out to me one fine trunk, ten inches in diameter, in the part exposed, lying just on the top of the yellow clay. The quantity of wood no doubt indicates the estuarine origin of the silt, and the comparative freshness and excellent state of preservation of the driftwood bears witness to the imperviousness to water of the protecting silt.

The arca band extends continuously throughout the cutting at about the same horizon. Mr. Davies also noted it at the same level in a slip cut 500 feet north of the canal.

I have already said that the bed has been met with in the river dredgings, but I have no record of the reaches of the river in which the shells were found. Captain Synnot informs me that when digging out his dock near what is now Langland's Foundry (close to Wright and Orr's present dock, and a mile and a half from the nearer entrance to the canal), he came upon shells, and Mr. John Macaulay, who acted as foreman during the construction of the dock, assures Mr. Davies that the shells were those of the "Blood Cockle," which is the old colonists' name for the arca. I can obtain no evidence of shells having been found in Wright and Orr's new dock. In the river bed the silt ceases, as we go up stream, at about the crossing of the Steam Ferry, at Spencer-street; at and above this was a patch of rock which has been removed by the Trust. The rock crops to the surface again at the Falls Bridge, and occurs as more or less of an obstruction to a point about 300 yards above Prince's Bridge. Where the rock is covered above the ferry the covering consists, as far as I can learn or judge, of the yellow clay; but silt may exist as flood deposit, not, I expect, as a strictly estuarine deposit, in the South Melbourne swamps. I had purposed paying a visit of inspection to the cutting for the Yarra embankment, above Falls Bridge, but the water got in, I believe prematurely, and I was prevented from carrying out my intention. I have not, therefore, been able to ascertain whether the arca occurred here or not. I think not, but, from actual observation, the arca bed has been found stretching to a distance of three, and perhaps five, miles inland from the present shore.

I have made inquiries into the present habitats and distribution of the two molluscs characteristic of this bed. Though I have taken considerable pains during my four years' residence in Melbourne to acquaint myself with the locale and habits of the mollusca of the bay, I have never seen living *animals* of *Arca trapezium*. I have found live shells thrown on the shore between Brighton and Cheltenham, and dead shells are frequent on the sands between St. Kilda and Sandridge. I have dredged in Laverton Bay and at Sandridge, but never obtained living specimens; still I believe the animals are living somewhere off Williamstown. Mr. Tope informed Mr. Davies that he had taken the animals alive many years ago near Williamstown; and Mr. W. Kershaw, of the National Museum, obtained

them by wading near the mouth of the river on the Sandridge shore.

Rev. J. E. Tenison-Woods, in his "Census of Tasmanian Shells," quotes *A. trapezium* as "frequent at Tamar Heads at low water." But on communicating with my friend, Lieut. Beddome, of Hobart, a high authority on Tasmanian shells, he forwards to me specimens of *A. fasciata* as being the species abundant among the rocks at Tamar Heads. I have often found *A. fasciata* in holes in the rocks just below low water at Williamstown, Cheltenham, &c. I think that *A. trapezium* occupies muddy bottoms, in comparatively deep water.

With regard to the present habitat of the mud oyster, Mr. Bracebridge Wilson writes me that he has dredged them alive in Corio Bay. I have it also from Ernest Myers, a Sandridge fisherman, that they are occasionally to be found in Port Phillip. Mr. Wilson says that the dead shells are abundant in the South Channel, and adds that a fisherman, named Mentiplay, used to dredge live oysters for sale from that locality.

The silt is very fine, and is from pressure compact and impervious to water. That this property has been of service in the preservation of the shells is seen from the effect produced upon them when exposed to the action of the river water. I have never found any concretions in the shell-layer in the canal itself. They are frequently brought up in dredging from the river. Mr. Davies obtained them *in situ* from the shell bed in the slip mentioned as cut some 500 feet from the east end of the cutting. No water came out of the silt until the shell band was reached; then water oozed out in quantity. I have no doubt that this was derived horizontally from the river, and that the access in this way of river water has produced these calcareous concretions. The smaller shells, where acted upon by water, have yielded up to it their lime, and this, carried in solution, has penetrated between the grains of silt, uniting them into an excellent "cement." The heart of the concretions is still dark silt. All stages of the process are visible from the unaltered shells, still distinct in outline, though united into a cluster by a hard cement, until we reach the nodular concretion of indefinite shape. In the case of the thinner shells only has the process been completed. The thick dense shells of the arcas have in very few cases yet succumbed, but they manifest signs of the initial stages.

The silt continues above the shelly stratum for 6—12 feet. It consists, no doubt, of the fine mud brought down by the old Yarra, and is almost as fresh, though more consolidated, than that now to be dredged off Williamstown. On burning a small fragment by way of experiment, I found that it formed a red and, I should judge, not very bad brick. No bones of mammals have been detected. I looked very closely for any fresh-water signs, but no *Unio* or *Corbicula* rewarded my search. The whole was almost certainly estuarine in formation, though the upper part of the silt was generally devoid of animal remains of any kind.

The junction plane of silt and sand is distinct. There is no break in the conformity. The lower layers of the sand contain next to no shells. At the east end of the excavation the vertical section of the sand exhibits much cross-bedding, due to play of currents, but I could see no trace of shells. The sands here were bound together in places by a ferruginous cement, and preserved a vertical face. At the west end, on the contrary, the sands were very loose, and at about the level of present low-water mark (or a foot below) a very good example of an old beach is preserved in the form of a narrow 4—6 in. band, crammed with remains of shells such as one finds nowadays piled on the shore near low-water mark at Sandridge. Dead shells most of them, some bored by *Naticas*, while some few sand burrowers, as *Solen*, *Pholas*, and *Mesodesma*, clearly lived on the spot. How far this layer of shells extended along the canal I am unable to say, as the sands of the side-slopes towards the west had, from their incoherence, to be protected and covered by sheet-piling and pitching, even on my first visit to the ground. The west end of the canal is over 2 miles from the present shore of Hobson's Bay along the river.

Up to this shell-band, then, the sands are of marine origin, brought up by currents probably from the cliffs of Brighton, Cheltenham, &c. At Cheltenham the bed of shells occurs at a height of nearly 60 feet, and, as the cliffs were rising to this elevation, the wear and tear must have been very great. As the sand spread over the silt, a corresponding immigration of *Solens* and other sand-inhabiting forms took place. But the uppermost layers of sand have, I believe, not been laid down by water, but been blown in from the shores of Hobson's Bay. The process is, in fact, still going on where unchecked by vegetation, and where the Sandridge people have stripped the surface of fern it goes on with unpleasant